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# EXPERIMENTAL ANALYSIS ON MECHANICAL PROPERTIES OF CONCRETE WITH TREATED PULVERIZED WASTE FOUNDRY SAND AS MINERAL ADMIXTURE

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ABSTRACT.
Mineral admixtures are now widely used in the production of concrete along with chemical admixtures for enhancing the desired properties. The widely used mineral admixtures are fly ash, metakaolin, granulated blast furnace slag and silica fumes. The above- mentioned industrial waste by-products are treated with various process to meet the desired specifications of cement. Such type of product especially waste foundry sand (WFS) is being treated with some chemicals, pulverized and used as a mineral admixture. The Treated Waste Foundry Sand (TWFS) was pulverized to get Treated Pulverized Waste Foundry Sand (TPWFS). Various experiments are conducted to investigate the various strength parameters of concrete i.e., compressive strength, flexural strength, and splitting tensile strength of concrete with and without the inclusion of TPWFS. The concrete grade of M40 was designed and TPWFS was partially mixed to the concrete at the rate of 0%, 5%, 10%, 15%, and 20% of the cement content. The experiments are conducted on the concrete specimens at 7days and 28days curing period. The experimental results indicated that performance of concrete with TPWFS is far better than control concrete and showed that concrete with 15% TPWFS is having more strength than control concrete and also save the iron and steel foundries from the disposal problem.

Keywords: Compressive Strength, Flexural Strength, Splitting Tensile Strength, Treated Pulverized Waste Foundry Sand

## INTRODUCTION
The Waste Foundry Sand (WFS) produced from iron and steel foundries are rarely hazardous. The foundry sand produced from non-ferrous metal foundries can be directly used in concrete [1]. Due to a lack of beneficial reuse knowledge, only 15% of foundry sand is recycled. It has been found that WFS can be used as a partial inclusion to fine aggregates in structural concrete. There is more iron oxide in the cast sand provided from ferrous metal foundries, which reduces concrete properties and strength parameters. As per ASTMC330 and C641, the staining effect is induced by iron oxide in the sand, which also reduces the toughness of hardened concrete. To overcome this problem, iron content has to remove or reduce up to the desired limit from WFS. The iron content from WFS was removed by treating different concentration of HCL and named as Treated Waste Foundry Sand (TWFS) [2]. The TWFS was pulverized to get Treated Pulverized Waste Foundry Sand (TPWFS) powder. This fine powder is having a size similar to cement particles. So, the TPWFS can be used as a mineral admixture in the production of concrete. N. Gurumoorthy et al [3] studied that the WFS treated with 2.5% concentration strong acid contains 70-75% silicon dioxide and 5-10% iron oxide and WFS treated with 5% concentration HCl contains 70-85% silicon dioxide and 2-4% ferrous oxide respectively. Treated TWFS 5%(v/v) concentration Hydro Chloric acid has more cementing property than raw WFS and treated WFS with other concentration.
Mineral admixtures are now widely used in the production of concrete along with chemical admixtures for enhancing the desired properties. As per ASTM C125-15b, the mineral admixtures are generally used for modification of the properties of fresh concrete that is added to the batch before or during its casting [4]. Ashfi et al. [5] contrived the effect of mineral admixtures on high strength concrete which

results that addition of silica fume to concrete increases in various strength properties of concrete at all ages. The result shows that the inclusion of cement by fly ash and slag lead to improve the workability up to a replacement level of 30 %.

There are many research papers which are based on the various strength parameter of concrete with mineral admixtures like fly ash, metakaolin and silica fume. It is established from previous researchers that pulverized untreated WFS can be used as a mineral admixture. The study of WFS as a mineral admixture in concrete structures becomes more interesting. As no literature are available on the properties of structural concrete with TPWFS, it signifies that addition of TPWFS in concrete as mineral admixture held importance in modern day scenario. The mechanical pulverisation of TWFS is used to bring the similar properties of cement which set the motivation of the proposed study.

In the present study, TWFS was pulverized to get TPWFS. Various experiments were conducted to analyse the various strength properties of concrete having TPWFS as partial inclusion of cement. The concrete grade of M40 was designed and TPWFS was partially added to the concrete mix at the rate of 0%, 5%, 10%, 15%, and 20% of the cement content. The experiment was conducted on the concrete specimens at 7days and 28 days curing period. The obtained results are then compared with different percentages of replacement of TPWFS with a binder for each proposed parameter.

## EXPERIMENTAL INVESTIGATIONS

### Materials

#### Cement

The cement used is of 53 grade of Ordinary Portland Cement for the experiment with a specific gravity of 3.12. The cement conforms to IS: 12269-2013 [6].

#### Fine aggregates

The fine aggregates used are natural river sand which has 4.75 mm nominal size conforming to ASTM C 33/M-13 [7]. The specific gravity of fine aggregate is 2.68 and belongs to zone- II.

#### Coarse aggregate

The coarse aggregates used are crushed angular granite having 20 mm nominal size as per IS: 383-1970[8]. The specific gravity of coarse aggregate is 2.80.

#### Super plasticizer

Sulphonated Naphthalene formaldehyde chemical-based superplasticizer has been used for increasing the workability of fresh concrete. The dosage is taken constant for all concrete mix which is 0.5% by weight of binding material.

#### Treatment of WFS

The WFS is collected from ferrous metal casting foundry near Mancheswar, Bhubaneswar, Odisha. WFS is treated with a 5% concentration of HCl acid as followed by N. Gurumoorthy et al. [3]. By adding 100 g of WFS with 475 ml of water and 25 ml of hydrochloric acid, properly mixed and stirred with a magnetic stirrer for 24 hours, the 5% concentration of HCl solutions is prepared as followed by Monosi, et al. [9]. After 24 hours of observation, the solutions are centrifugated and pass through 0.2 mm filter paper. The resulting WFS is cleaned thoroughly with distilled water. Again, the collected WFS is disarticulated and dried for 24 h. From the laboratory test report, it is perceived that the WFS sample contains 9.81% iron oxide. WFS treated with 5% concentration of HCl contains 3% iron oxide. The resulting samples are termed as Treated Waste Foundry Sand (TWFS).

#### Pulverization of TWFS

Waste foundry sand has been treated with a 5% concentration of HCl solutions. The treated used foundry sand was then pulverized using a mechanical sand pulveriser to get Treated Pulverized Waste Foundry Sand (TPWFS). The TPWFS is shown in Figure 1.

Figure 1 Treated pulverized waste foundry sand The Physical properties of TPWFS are noted in Table 1.

Table 1 Physical properties of TPWFS

| Physical property | Obtained value |
|---|---|
| Specific gravity | 2.28 |
| Bulk density | 428 kg/m$^{-3}$ |

Mix Proportions and Specimen Casting

Control Concrete (CC) is rated to have a compressive strength of 34.28 MPa and 46.75 MPa for 7 days and 28 days, respectively, as per IS: 10262-2009[10]. Having a W/C ratio of 0.36, the construction mix of concrete was 1:1.60:3.08. Four additional concrete mix designations T5, T10, T15 and T20 are prepared where cement is partially substituted as mineral admixture by cement mass with 5%, 10%, 15% and 20% TPWFS respectively. The slump is held at 100-120 mm for all concrete mix proportions. The TPWFS-containing concrete mix proportions are tabulated in Table 2. For measuring compressive strength, 150 mm in diameter and 300 mm in height, 150 mm x150 mm x150 mm concrete cubes are prepared for cylinder specimens for split tensile strength of concrete and 100mmx100mmx500mm beams for flexural strength of concrete. In accordance with IS: 1199-1959 [11], each specimen is cast. Concrete specimens are held for 24 h at a temperature of about 27 ± 10C after casting. After 24 h, the specimens are then demoulded and submerged for curing before the time of testing. For study, the average value of the three concrete specimens evaluated for each test is noted.

Table 2 Concrete mix proportions containing TPWFS.

| Mix ID | Cement (kg/m$^{-3}$) | Coarse aggregate (kg/m$^{-3}$) | Fine aggregate (kg/m$^{-3}$) | TPUFS (kg/m$^{-3}$) | Water (ltr/m.$^{3}$) | Super plasticizer (ltr/m$^{-3}$) |
|---|---|---|---|---|---|---|
| C C | 420 | 1295 | 674 | 0 | 151 | 1.83 |
| T5 | 399 | 1295 | 674 | 21 | 151 | 1.83 |
| T10 | 378 | 1295 | 674 | 42 | 151 | 1.83 |
| T15 | 357 | 1295 | 674 | 63 | 151 | 1.83 |
| T20 | 336 | 1295 | 674 | 84 | 151 | 1.83 |

EXPERIMENTAL RESULTS AND DISCUSSION

Five mixtures of concrete are designed to study the effect of different percentage of inclusion of TPWFS on the various strength characteristics of concrete at different curing ages. The results were compared to the variation of different percentage of inclusion of TPWFS with the binder for each parameter.

Compressive Strength

Compressive strength was measured and the obtained results at different ages are shown in Figure 2 and also in Table 3. The compressive strength of control concrete mix is obtained

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46.75 MPa at 28 days and the mix designation T5 to T20 obtained strength is greater by 7.57%, 10.13%, 15.27% and 7.82% respectively. It is showed that inclusion of TPWFS improves in strength at 7 day and 28 days. The strength at 15% replacement level is higher than the other percentage of inclusion of TPWFS due to the densification of the concrete [12]. The densification of concrete is due to the availability of very finer particles in WFS. It may help in concrete to reduce the void up to a certain limit. The strength decrease may be due to different type of binder and the presence of different impurities in WFS. The compressive strength of concrete is increasing with the percentage increase in TPWFS up to 15% and decreasing afterwards for all curing ages. At 7 days the compressive strength increased at 2.74%, 5.16%, 13.03% and 3.20% of the control concrete mix for 5%, 10%, 15% and 20% inclusion of TPWFS respectively.

Table 3 Compressive strength of concrete mixes at different ages

| Mix designation | Compressive strength (MPa) | |
|---|---|---|
| | 7 day | 28 day |
| CC | 34.28 | 46.75 |
| T5 | 35.22 | 50.29 |
| T10 | 36.05 | 51.49 |
| T15 | 38.75 | 53.89 |
| T20 | 35.38 | 50.41 |

The variation of compressive strength w.r.t the percentage of replacement of TPWFS is shown in Figure 2.

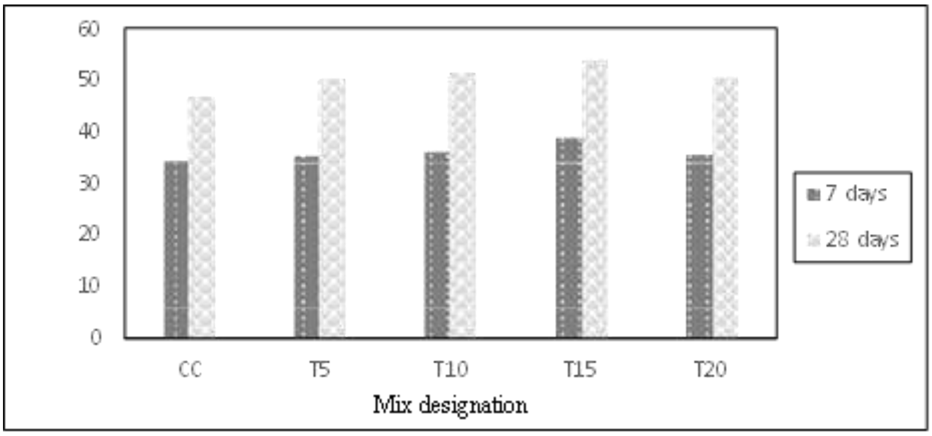


Figure 2 Variation of compressive strength with different TPWFS contents at 7 &28 days

Splitting Tensile Strength

Figure 3 and Table 4 showed the behaviour of splitting tensile strength with different TPWFS. It is obtained that splitting tensile strength of T5, T10, T15 and T20 mixes at the curing period of 7 and 28 days show the higher value then referred concrete specimen. The strength is increased at 6.66%, 13.3%, and 17.70% for T5 to T15 mixes, and is decreased at 6.66% for T20 mix at the age of 7 days. Similarly, strength increases by 9.90%, 16.34%, 18.58% and 13.14% at 28 days for T5 to T20 mix respectively as compared to referred concrete mix.

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Table 4 Splitting tensile strength of concrete mixes at different ages.

| Mix designation | Splitting tensile strength (MPa) | |
|---|---|---|
| | 7 day | 28 day |
| CC | 2.25 | 3.12 |
| T5 | 2.40 | 3.43 |
| T10 | 2.55 | 3.63 |
| T15 | 2.65 | 3.70 |
| T20 | 2.40 | 3.53 |

The variation of splitting tensile strength w.r.t the percentage of inclusion of TPWFS is shown in Figure 3.

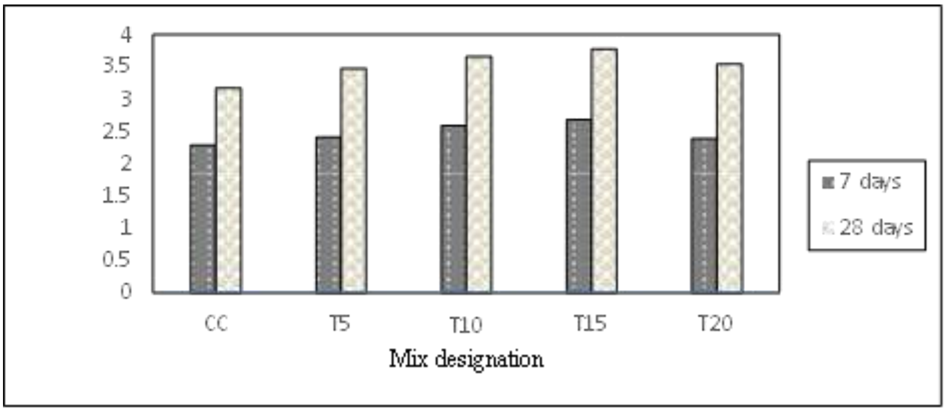


Figure 3 Variation of splitting tensile strength with different TPWFS contents at 7&28 days.

Flexural Strength

The ability of unreinforced beam to resist the failure in bending due to applied loads is known as flexural strength. It is evaluated from beam tests on specimens of size 100x100x500mm size as per IS: 516-1959. The distance between the supports was at 400mm. Two-point loading system was adopted to determine the modulus of rupture concrete. Point loads were subjected at 1/3rd span. The experimental results of the flexural strength of concrete using various percentage of inclusion of TPWFS are shown in Table 5. The flexural strength of concrete is increasing with the increase in percentage addition of TPWFS up to 15% and tends to decrease afterwards. At 7days the modulus of rupture increased at 12.63%, 22.89%, 24.21% and 15.26% of the control concrete mix for 5%, 10%, 15% and 20% addition of TPWFS respectively. At 28 days the modulus of rupture increased at 18.75%, 23.95%, 28.12% and 18.75% of the control concrete mix for 5%, 10%, 15% and 20% addition of TPWFS respectively.

Table 5 Flexural strength of concrete mixes at different ages.

| Mix designation | Flexural strength (MPa) | |
|---|---|---|
| | 7 day | 28 day |
| CC | 3.80 | 4.80 |
| T5 | 4.28 | 5.70 |
| T10 | 4.67 | 5.95 |
| T15 | 4.72 | 6.15 |
| T20 | 4.38 | 5.70 |

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The variation of flexural strength w.r.t the percentage addition of TPWFS is shown in Figure 4.

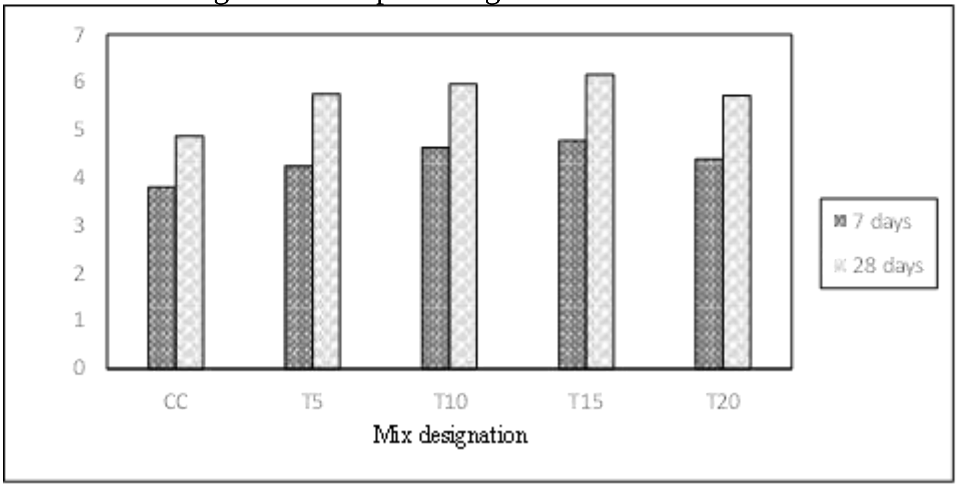


Figure 4 Variation of flexural strength with different TPWFS contents at 7&28 days

CONCLUSIONS

- In the present study, the concrete with treated pulverized waste foundry sand as mineral admixture has slightly more strength than referred concrete specimen.
- The compressive strength of concrete with inclusion of 15% TPWFS gives maximum strength then 20% TPWFS. The strength increase may be due to the availability of fine particles in TPWFS, which helps to minimize the void ratios to a certain extent.
- The split tensile strength of concrete attributes maximum strength at 15% and then gradually decreases to 20%. The reason behind the decrease in strength at 20% replacement, may be due to disruption of aggregate particle packing, or it may contain more fine-sized TPWFS material at high replacement level, and it is also suspected that TPWFS may weaken the concrete interfacial transition zone.
- It is shown that when 15% TPWFS are replaced with cement, the overall flexural strength of concrete was found to be 26.22 percent greater than control concrete. Nevertheless, up to 20% inclusion of TPWFS the flexural strength is more than that of control concrete.

The paper suggests that TPWFS can be considered for developing sustainable structural concrete. The experimentally obtained results of the present work will provide references in the manufacturing of mineral admixtures as well as can save the iron and steel foundries the issue of waste disposal and the development of greener concrete for construction.

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